

The Context of Demarcation in Nature of Science Teaching: The Case of Astrology

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Abstract The aim of developing students' understanding of the nature of science [NOS] has been considered an important aspect of science education. However, the results of previous research indicate that students of various ages and even teachers possess both inaccurate and inappropriate views of the NOS. Such a failure has been explained by the view that perceptions about the NOS are well assimilated into mental structures and resistant to change. Further, the popularization of pseudoscience by the media and the assimilation of pseudoscience into previously established scientific fields have been presented as possible reasons for erroneous popular perceptions of science. Any teaching intervention designed to teach the NOS should first provoke individuals to expose their current ideas in order to provide them the chance to revise or replace these conceptual frameworks. Based on these assumptions, the aim of this study was to determine whether a teaching context based on the issue of demarcation would provide a suitable opportunity for exposing and further developing the NOS understandings of individuals enrolled in a teacher education course. Results indicate that a learning intervention based on the issue of demarcation of science from pseudoscience (in the specific case of astrology) proved an effective instructional strategy, which a majority of teacher candidates claimed to plan to use in their future teachings.

1 Introduction

The development of individuals' understandings of the nature of science (NOS) has been considered an important aim of science instruction (American Association for the Advancement of Science [AAAS] 1989; Duschl 1990; Meichtry 1993; National Research Council [NRC] 1996; Kang et al. 2005) and various rationales and practical proposals for teaching the NOS have been put forward (Duschl 1990; Matthews 2000; Bravo et al. 2001). Such an aim has been emphasized in many science education reform efforts (Lederman et al. 2002) and science educators have indicated the need for educational practices to

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focus on the NOS (Aikenhead 1997). However, little has been done to provide specific instructional methods to enhance the development of NOS understanding (Scharmann et al. 2005), even within reform documents themselves.

Furthermore, as a consequence of diverse definitions developed over several decades, researchers appear not to share a common conception of the NOS (Abd-El-Khalick et al. 1998; Kang et al. 2005). Philosophers, historians and sociologists of science are quick to disagree on specific NOS-related issues (Lederman et al. 2002) and have proposed different views about what science is, including different rationales for how it works. In fact, conceptions of the NOS are dynamic and have changed throughout the development of science. Therefore, our current views on the NOS are themselves likely to evolve as our understanding of the universe increases (Suchting 1995). However, most of these disagreements about the NOS are seen to be irrelevant to science education, especially for grades K-12 (Abd-El-Khalick and Lederman 2000b); the issue of the existence of an objective reality compared with phenomenal realities (Lederman et al. 2002) serves as an example. So, despite specific professional conflicts, the shared wisdom (although not complete agreement) among philosophers of science at a certain level of generality about the NOS (Smith et al. 1997) should be said to constitute a common ground, at least for purposes of science education.

At this point, it seems obvious that a useful starting place would be to articulate a generally accepted definition of the NOS used in science education research, which will also clarify the meaning given to the NOS in this study. Broadly speaking, then, the NOS refers to both the epistemology and sociology of science as a way of knowing, which includes the values and beliefs inherent in scientific knowledge (Lederman 1992) and understanding of social practices, the organization of science and how scientists perform scientific investigations (Ryder et al. 1999). This perspective underscores some aspects of science such as its (1) tentativeness; (2) empirical nature; (3) theory-laden nature; (4) socio-cultural embeddedness; (4) myth of a universal scientific method; as well as the roles of (5) hypotheses, theories and laws; (6) creativity and imagination; and (7) persuasive communication. This definition is aligned with a basic understanding of the NOS which has been discussed in documents such as the *Benchmarks for Scientific Literacy* and the *National Science Education Standards* (Smith and Scharmann 1999; McComas et al. 2000; Lederman et al. 2002). So, without ignoring philosophical debates about the complexity of specific issues, these aforementioned aspects of the NOS should establish a foundation that is accessible to K-12 students (Lederman et al. 2002). Such a consensual definition is crucial as it provides a framework for teaching the NOS in science classes.

The related literature indicates two general arguments in favour of teaching the NOS, which Bravo (2004) has named the ‘curriculum perspective’ and ‘meta-theoretical perspective’. According to the curriculum perspective, which is based on democratic and cultural arguments, there is intrinsic value in teaching the NOS for the general education of citizens. An understanding of the NOS is seen as necessary for making sense of socio-scientific issues and participating in the societal decision-making process (Driver et al. 1996; Zeidler et al. 2002), as well as critical for effective local and global citizenship (Smith and Scharmann 1999). Furthermore, this view claims that being an educated citizen of the twenty-first century requires not just knowing science but also knowing about science, how it is created, how it evolves through history and how it relates to society and culture (Bravo et al. 2001). On the other hand, from the meta-theoretical perspective, the NOS is assumed to represent a second order reflection on the content and methods of science that positively contributes to teachers’ pedagogical autonomy, especially when transforming professional science into school science (Bravo 2004). This second

perspective views teachers as the most important educational actors, and asserts that NOS instruction is central to their preparation.

While much emphasis has been placed upon NOS teaching, the results of previous research concerned with improving students' NOS understandings indicate that students of various ages and even teachers possess both inaccurate and inappropriate views of the NOS (Lederman 1992; Duschl 1990; Abd-El-Khalick and Lederman 2000a); these findings hold regardless of the instruments or methods used in investigations. Such a failure could be explained by the view that perceptions about the NOS are well assimilated into mental structures and resistant to change (Meichtry 1992). In addition, the popularization of pseudoscience by the media and the assimilation of pseudoscience into previously orthodox scientific fields should be taken into account as possible contributors to commonly-held erroneous formative perceptions of science (Castelao 2002). So any instructional sequence in which an individual's existing conceptions about the NOS are not brought to light would fail to provide learners the opportunity to reflect on or replace those current (incorrect) conceptual frameworks. Furthermore, science teachers should help illuminate all aspects of their students' diverse worldviews (religious beliefs, cultural values, philosophical beliefs, etc.), even the ones held in contradiction to modern science, in order to provide opportunities to teach and argue about the NOS. This need to confront students' belief systems suggests a significant pedagogical dilemma: designing an instructional context meaningful enough to help individuals become aware of and examine their own conceptual frameworks related to the NOS.

This study focused on the problem of designing such an instructional context. The issue of demarcation, based on philosophical schools of thought such as logical positivism, falsification, scientific revolutions and research programs (Bauer 2002; Lakatos 1981; Nickles 2006), was proposed as one that would potentially uncover students' prior conceptions of the NOS and allow for the purposeful examination of those conceptual frameworks. The topic of astrology was chosen to allow students to apply and debate demarcation issues in a specific context: when faced with the question of whether astrology was scientific or pseudoscientific, what would be students' arguments in favour of one category or the other? In addition, what would their arguments tell us about their understandings of the NOS? To this end, the main purpose of this research was first, to question the effectiveness of the context of demarcation for exposing students' NOS understandings. A secondary purpose of the research was to ascertain pre-service science teachers' views about the use of such a context in the elementary science education.

The instructional treatment of the status of astrology was considered to be a process, in which the intention was to remain open to individuals' views (including the pseudoscientific ones) without sacrificing the goal of understanding basic aspects of the scientific enterprise. Hence, an argumentative process involving a diversity of discourses was planned, but in a sense to prevent the inclusion of other ways of knowing (e.g. the attempts to broaden the definition of science in order to treat ideas originated from other ways of knowing as science contents) in a manner of curricular multicultural science education (El-Hani and Mortimer 2007). Astrology was introduced in the context of attempts to demarcate science from pseudoscience, where pseudoscience was presented as a set of ideas which claim to be scientific but contrary to science, are not tested empirically or in principle cannot be tested (Preece and Baxter 2000). The discrepancy between pseudoscience and nonscience was highlighted to prevent any possible conflicts that could be difficult to solve in science classes, such as those between religious and scientific ideas. This required a closer look at the issue of demarcation, and the next section details the theoretical basis of this issue as the context for this study.

2 The Issue of Demarcation

The problem of demarcation—identifying the criteria for differentiating science from nonscience/pseudoscience—has been the central issue of dominant philosophies of science since the early twentieth century, and still remains unresolved (Nickles 2006; Gillies 1998). Many of the criteria proposed by various philosophers of science were marked as either too narrow or too wide, or found to be generally unsatisfactory. In fact, some have argued for the impossibility of identifying certain criteria for a clear-cut demarcation of scientific areas of inquiry from nonscientific ones (Mahner 2007; Laudan 1983). The result of a survey conducted with 176 members of the Philosophy of Science Association in the United States exemplifies that contention, as about 89% of the respondents denied any consensus for universal demarcation criteria (Alters 1997). However, the absence of any widely accepted set of criteria does not mean the issue of demarcation is nonsensical or can be overlooked.

In some cases, controversies (as processes) themselves would be more valuable than their conclusions. Thus, philosophical arguments about the nature of reliable knowledge and methodologies to capture it (and thus about science) might be taught and used effectively in science education (Matthews 1998; Irez and Cakir 2006). Such instruction requires a systematic analysis of the issue be performed with the help of some guiding themes or questions, in order to present that controversy in a meaningful manner. This technique may be especially appropriate for teachers of science who are interested in the NOS but do not have deep knowledge in the philosophy of science.

In this study, guiding themes and questions were developed from authors such as Thagard (1988) and Laudan (1983) in an attempt to examine the general issue of demarcation. These themes took shape as: (1) Rationale for Demarcation; (2) Science versus Nonsense/Pseudoscience; and (3) Philosophical Arguments and Criteria Proposed.

2.1 Rationale for Demarcation

Mahner (2007) identified a theoretical as well as a practical reason to strive for the demarcation of science from nonscience. Theoretically, he highlighted the simple fact that every field of knowledge should be presented roughly for what it is about and what its objects of study are. But, he emphasized that such a basic distinction between science and nonscience should not be assumed to be pejorative; nonscientific forms of cognition and knowledge should not be marked as necessarily bad or inferior. Mahner used arts and humanities disciplines as examples to stand against such a possible pejorative attitude, since few would doubt their legitimacy and value despite their nonscientific standing. Here, the term nonsense should be viewed carefully, as these examples of it are not taken to be the equivalent of pseudoscience.

Mahner's (2007) practical justification for demarcating science concerns the 'normative aspect' of the distinction between science and pseudoscience. Such practical demarcation was also central to the present study and could be a matter of particular concern to science educators wherever pseudoscientific beliefs have a growing and widespread acceptance (Preece and Baxter 2000). The prevalence of practices such as therapeutic healing methods, magical cures, clairvoyants and dowsers help illustrate why the distinction of science from pseudoscience should be seen as vital not just to physical, but also to cultural and political life (Laudan 1983; Preece and Baxter 2000; Mahner 2007).

Theoretical and practical rationales for developing demarcation criteria between science and nonscience may be easily accepted. However, confusion which stems from the misuse

of the terms nonscience and pseudoscience has created some conflict in related literatures. The differences between these constructs are further clarified in the following section.

2.2 Science Versus Nonsense/Pseudoscience

The issue of demarcation should be addressed as the distinction of science from nonscience or pseudoscience, but the loaded meanings of these terms must be clarified. The question of whether pseudoscience should be taken as synonymous with nonscience emerged as an important point in the context of demarcation. As seen above and elsewhere (see Laudan 1983; Mahner 2007), the term *nonsense* has been typically clarified by the use of examples such as the arts, humanities disciplines, literature and religion. These fields are not usually considered scientific, and their ontological and epistemological presuppositions vary from those of the natural sciences. So the term *nonsense* is to be understood as an inclusive concept involving various fields of knowledge (whose natures and differences from scientific fields could be discussed philosophically in detail) which do not profess to be scientific. The term *pseudoscience* is quite different, since the disciplines falling into this category typically claim to be scientific (as in the case of astrology), although they do not meet various standards mentioned by philosophers of science (Preece and Baxter 2000). This distinction is especially important for science educators, in that controversies regarding science versus nonsense should be abandoned in favour of consideration of the conflicts between science and pseudoscience.

Arguments related to demarcation issues should be approached differently according to the field under consideration. The demarcation between science and nonsense may be discussed philosophically since philosophers of science are interested in the cognitive activities and practices leading to propositional knowledge. This interest involves the extent to which nonscientific cognitive fields propose hypotheses and theories as well as the procedures for these to be tested and leads the rejection of the classical science/metaphysics demarcation extending to all nonscientific epistemic fields (Mahner 2007). However, such a widely held demarcation issue involving all the nonscientific epistemic fields would be confusing, unmanageable and meaningless in science education, in practice.

Evaluating nonscientific claims (e.g. metaphysical and religious claims such as the existence of God, the soul and the afterlife which do not assert to be scientific) in the same way as pseudoscientific ones in science classes would encourage irrelevant, unintended controversies and increase the risk of alienating some of the students. This should not be understood as a recommendation to exclude all of students' nonscientific claims from this context of demarcation, or not to take an interest in them. On the contrary, the aim should be the design of an effective context for students to become aware of and able to discuss the various conceptions which constitute their NOS understandings, including metaphysical ones. The restriction should implicate what exactly is to be demarcated; science versus pseudoscience instead of science versus nonsense. In such a context, some nonscientific claims (metaphysical, religious, etc.) can emerge within discussions that would be informative about individuals' conceptual frameworks and should not be labeled as 'pseudo'. Any pseudoscientific claim however, can be criticized with required objections.

This perspective distinguishing between the identification and treatment of nonsense and pseudoscience was central to this research and played a significant role in the examination of philosophical controversies within the class that was part of this study. If the premises of philosophers were about the demarcation of science from nonsense, the criteria they proposed to qualify science were highlighted instead of their interpretations

about the status of nonscience, in order to prevent possible departures from the focus of study. These specific philosophical controversies surrounding the issue of demarcation of science either from nonscience or pseudoscience are the focus of next section.

2.3 Philosophical Arguments and Criteria Proposed

The issue of demarcation can be traced back to the time of the ancient Greeks, when it existed as the problem of distinguishing knowledge from mere opinion (Laudan 1983; Nickles 2006). However, introducing such a vast historical accumulation would be confusing and impractical for purposes of science education. With that point of view the scope can be restricted; any problem directly focused on science or other forms of cognitive inquiry should be held in meaningful historical context. If the subject of analysis is modern science, it would make more sense to examine classical systematic attempts for a philosophical solution only for the period starting after the appearance of modern science. It is a widely held conception that such attempts began in history with the logical positivists and continued with Popper and others such as Lakatos and Kuhn (Laudan 1983; Nickles 2006; Dilworth 2006; Mahner 2007; Gillies 1998). Therefore, introducing the philosophical arguments related to modern science with logical positivism should be appropriate.

The main goal of the logical positivists was to demarcate science from metaphysics and to determine the meaningfulness of propositions through a focus on linguistic analysis, in which the meaningfulness of a proposition was evaluated semantically with the criteria of verifiability (Mahner 2007; Nickles 2006; Laudan 1983). According to this approach, science was thought of as a linguistic phenomenon and all epistemological relationships were claimed to exist between sentences in the language of science, whose subject-matter was limited to directly observable entities (Dilworth 2006). Within this school of thought, to verify a proposition was to seek its truth by empirical verification, which was seen to be the necessary condition for meaningfulness. The condition of verifiability or openness to empirical testing was thought to be a sufficient criterion for the distinction between science and metaphysics; by this standard, the propositions of modern science were labelled as verifiable, therefore valued as meaningful and worthwhile, whereas the metaphysical propositions were not.

However, this positivist thesis of verifiability as the core of demarcation was also the core of philosophical objections that most of the universal statements of scientific laws were not strictly verifiable via empirical method (Nickles 2006). Some proponents of logical positivism (e.g. Carnap) offered confirmation instead of verification as a criterion of demarcation, but the main problem was with the logic of induction; for this, no satisfactory solution was given (Mahner 2007). Critiques of verification and/or confirmation based on the problem of induction eventually brought about an alternative approach, falsification, which was asserted to be logically sound in a way that verification was not. But it must be noted that, the basic terms of meaningfulness proposed by the logical positivists (e.g. rightfully scientific language consisting in logical operators and terms referring to what is directly observable) had been so influential even on the severest critics of logical positivism; they did not challenge the program for this (Dilworth 2006).

Popper's (1963) notion of falsification was based on the rejection of inductive criteria of demarcation through verification/confirmation; from this perspective, a statement is scientific if and only if it is falsifiable at least in principle. Popper marked Einstein's theory of relativity as scientific because of its risky, easily falsifiable empirical claims such as the bending of light, whereas labelled Marx's or Freud's theories as pseudoscientific since their advocates did not allow any refutation. In addition to the rejection of inductive

perspective, Popper also diverged from the logical positivists by not labelling all metaphysical statements as meaningless. To him, although they are not scientific, such statements can serve as a heuristic for modern science and therefore the relevant issue is the demarcation of science from pseudoscience instead of metaphysics.

Being falsifiable is seen to be the most widely-cited criterion of demarcation but it did not take long for critiques against falsification to appear. It is criticised to be failed for unrestricted existential statements, such as “the existence of black holes” which can not be falsified since the search of the whole universe required for being logically conclusive (Ladyman 2007; Nickles 2006). In addition, Duhem’s (1954, cited in Nickles 2006) claim that theories such as classical mechanics cannot be falsifiable in isolation, and arguments about psychological and social determinants related to the behaviour of scientists were also raised against falsification. The actual details of scientific practice itself did not always match Popper’s falsificationist criterion, since some scientific theories could not be falsifiable alone and because scientists did not readily abandon their theories just because of some falsifying data (Lakatos 1981).

In response to the first group of critiques, Popper proposed logical falsifiability rather than practical one. According to this view, science merely requires logical falsifiability, for which one conceivable contradictory observational statement is needed. A well-known example Popper used for this standard of demarcation was psychoanalysis. However, it has been argued that although some claims of psychoanalysis are indeed unfalsifiable, many others are falsifiable and others have actually been falsified (Mahner 2007). Therefore, although falsification is useful to distinguish some claims as pseudoscientific, it also allows for the acceptance of too many marginally falsifiable statements as scientific. Such critiques eventually built a strong base for the rejection of both practical and logical falsifiability with the discussion about the units to be examined for being pseudoscientific (Kuhn 1970; Lakatos 1970), and the focus of demarcation shifted from individual statements or hypotheses to entire theories and disciplines.

The notion of research programs as a sequence of theories—in which each theory is formed either by reinterpretation of the previous one or by the addition of some auxiliary assumptions—should be viewed within this shift of the focus of demarcation (Lakatos 1970). The theoretically progressive nature of a research program was identified as the required criterion for being scientific and a research program was assumed to be progressive if new theories had a greater explanatory power than those they replaced or led to the discovery of new facts, according to Lakatos (1970). In contrast, pseudoscientific research programs were so because of their degenerative character. However, some critiques (similar to the ones against falsifiability) were directed toward the criteria of progressiveness (e.g. Laudan 1983); for instance, progress might occur in nonscientific fields, and some branches of science might not progress much during some periods in their history (Mahner 2007). But, it must be noted that if the terms nonscience and pseudoscience are differentiated carefully in the way outlined above, criticism based on the idea of possibility of progress also in nonscientific fields (philosophy was given as the sample in the related article by Mahner) would be nonsense. On the other hand, some arguments that seem to be speculative in nature but possible in practice (e.g. notions related to the end of science), or radical new theories which have not been a part of a progressive research program yet (Mahner 2007) should be considered seriously.

As was the case with Lakatos, Kuhn (1970) offered a different perspective which shifted the demarcation focus away from the classical testability of theories and instead highlighted their problem solving capacities. Kuhn concluded that astrology is not scientific just because it lacks testable/falsifiable predictions, but rather, because it is better understood as

a craft; it is devoid of disciplinary puzzles to solve in the sense that failed predictions do not entice its community to engage in any problem solving activities. According to Kuhn, the indicator of a mature science is its disciplined determination of proposing fruitful problems within a recognizable paradigm (i.e. ‘normal science’). He emphasized the commitment to a tradition of problem-solving practices rather than to a set of specific beliefs and methodological rules (Rouse 2003) and asserted “scientific revolutions” which are forced by anomalies in the puzzle-solving attempts of normal science, instead of the idea of “cumulative progress” in science. This commitment, and the implicit practical knowledge that scientists possess within a specialist community is suggested by Kuhn’s work as a criterion for demarcating science from pseudoscience. But this idea of paradigmatic harmony appears to disappear during a scientific revolution and seems to make the issue of demarcation more confusing. In addition, the criticisms that paradigms could not be scientific themselves since they are claimed to be convergent, uncritical and closed to falsification—their constitutive principles retain a virtual a priori status for scientific community—are also considerable (Nickles 2006).

Within these endless controversies, various arguments advanced by others such as Kitcher (1982), Thagard (1988) and Dilworth (2006) could also be mentioned. However, the result of this overview remains: neither a single criterion nor a set of criteria can undisputedly serve to qualify an activity as science and hence demarcate it. Laudan’s (1983) position on this issue could be adopted as a reminder that some crucial epistemological and methodological questions can be raised about knowledge claims whether classified as scientific or not, at least for educational purposes. As such, his assertion about the issue of demarcation that it is a pseudo-problem (at least philosophically) should also be understood better with the rationale behind it. Further, as mentioned before, controversies themselves are often more pedagogically beneficial than their conclusions, if they can be structured in meaningful and manageable ways.

3 Study Design

The present study made use of a qualitative research approach in attempting to explore and interpret whether the issue of demarcation, as made visible through the case of astrology, provides an effective context to introduce and argue about students’ existing framework of conceptions about the NOS. In the research design, various data sources were utilized for an in-depth exploration of practice (Creswell 2005; Merriam 1998; Miles and Huberman 1994) and an intensive, holistic description and analysis of the participants’ NOS-related conceptual constructs was aimed (Merriam 1998). The participants formed a social unit in the class and the context of the issue of demarcation based on the case of astrology was introduced to them. The researcher acted as a participant observer and conducted a thorough analysis of the pedagogical process using a variety of data (Glesne 2006) including recorded observations and student work samples.

3.1 Participants and Course Context

The study was conducted in a state university in Istanbul, Turkey. The participants were 46 pre-service science teachers (26 males and 20 females, ages ranging from 20 to 25) who were enrolled in a Science-Technology and Society course. The course was taught by the researcher for 3 h a week for a period of 12 weeks and also included some out-of-class research by the participants. The central theme of the course was presented as scientific

literacy with a focus on the NOS and an outline was given to the participants at the beginning of the term. All the participants had completed science courses required by the teacher education program such as physics, biology and chemistry, but none of them had any prior instruction related to the nature, history and philosophy of science. The 12-week period planned for this course was divided into two phases, (1) theoretical preparation for the issue of demarcation and (2) controversy around the sample case of astrology.

In the initial phase, which covered the first 2 weeks of the course, common aspects of the NOS were presented and discussed in class. Then some philosophical schools of thought—logical positivism, falsification, scientific revolutions and research programs—were assigned to participants for research. Such a process was planned especially for establishing a common and rich terminology about demarcation, including the units of scientific practice (i.e. hypotheses, theories, research programs) to be demarcated. All participants researched the fundamental premises of these philosophical schools of thought and prepared short reports before coming to class. These short reports aimed to prepare the participants for the lessons and especially for the discussions to be performed within the class. In a period of 6 weeks the assigned philosophical schools of thought were discussed in class and at the end of this time, some criteria for demarcation of science from pseudoscience were identified by the participants working in groups of four to five.

After the participant groups listed their criteria for demarcation, the research moved onto the second phase; a brief history of astrology was presented to the class as a ‘discipline’ with its own assertions, without imposing any interpretation of its scientific merit. The general profile of activities conducted within the ‘discipline’ of astrology in various cultures (e.g. China, India) as described in various written sources was reviewed in class (again, without labeling them as scientific or pseudoscientific) in order to establish a common ground for discussions. Then some videos of famous Turkish astrologers, as well as counter-arguments to the astrologers’ claims, were viewed in the class. The aim of this instructional period was to focus on the character of astrological activities instead of the popular products of it, such as the daily interpretations of astrological signs typically placed in newspapers. In this way, attempts were made to bring up arguments such as paradigm, problem solving capacity and progress and to talk of controversies in terms broader than the conception of strict experimentation (which participants apparently believed to constitute the core of science, from comments made during the first weeks of class).

Next, participants were asked to examine studies done by astrologers and arguments about astrology, in order to understand astrology from different points of view. With this initial background, the participants discussed astrology in class; based on this discussion, two groups formed for a controversy about whether or not astrology should be considered a pseudoscientific discipline. After a week’s worth of preparation for the activity, participants were actively engaged in a controversy between two opposing sides. The pedagogical purpose of the controversy was partly to expose and challenge participants’ alternative conceptions of the NOS (Hammrich 1997). Participants’ views of the scientific status of astrology and the rationales behind these views were recorded before and after this controversy. In the post-controversy reports, participants were asked to revisit the rationales they cited in pre-controversy reports, and to add new arguments if needed.

The course ended with group discussions about the pedagogical implications of the issue of demarcation in the school science curriculum. Participants considered whether the issue of demarcation could be used effectively in schools at the elementary level to help students develop more informed views about the NOS. During this last step, the participants evaluated their experiences in the course and prepared individual reflections which

included some discussion of their own instructional intentions related to developing similar NOS teaching contexts.

3.2 Data Sources and Analysis

Several data sources were used in this research, including coursework-related reports prepared by the participants and controversy notes and field notes of class observations made by the researcher. The reports prepared by the participants (either as a group or individually) were about the criteria for demarcation of science from pseudoscience, the status of astrology as scientific or not and the use of the context of demarcation in teaching the NOS. The controversy notes and field notes of class observations were recorded by the researcher as written memos during sessions and detailed afterwards.

Analyses of these data sources were performed gradually. The initial one was performed for group reports about the criteria for demarcation at the end of the first phase and was not directly related to core research questions. However, it provided the researcher with insight into the effectiveness of the theoretical preparation phase and presented the perceptions of the participants regarding the issue of demarcation in general. Analysis of the group reports focused on participants' understandings of the specific criteria of demarcation either proposed by relevant philosophers or by various authors researched and cited by the participants.

Subsequent analyses of participant coursework were aimed at interpreting the instructional process in terms of the research questions themselves, and were performed at the end of the research. The individual reports about the status of astrology were analyzed for answers to the first research question: the effectiveness of the context of demarcation for exposing and addressing the participants' NOS-related conceptual framework. The individual reflections about the use of similar cases in elementary science classes were analyzed for findings related to the second research question and were treated as the primary reflections of the participants about their experiences, perceived competencies and rationales for the whole instructional process. The controversy notes and field notes compiled by the researcher were used both to validate and triangulate the analysis in accordance with the data from participant coursework. In addition, a blind round of analysis performed by another researcher and the patterns identified within and across the reports of the participants were also used to enhance the validity of the findings. The data sources are summarized in Table 1 along with the basic intentions of their analysis.

The group reports on demarcation criteria proposed by various philosophers were analyzed by content and interpreted for emergent patterns (Berg 2007). A theory-driven approach was used to categorise the criteria mentioned in reports by aligning these with the

Table 1 Data sources and basic intentions of analysis

The intention of analysis	Data source
The effectiveness of theoretical preparation	Reports about proposed philosophical demarcation criteria
The effectiveness of the context of demarcation	Pre-controversy evaluations of astrology Post-controversy evaluations of astrology Researcher's controversy notes Researcher's Observation notes
Preferences for the use of the context	Individual reflections about the use of similar cases

philosophical arguments that were examined in the context of study. The categories emerging from the analysis were (1) criteria for knowledge claims, (2) criteria for disciplines and (3) criteria related to practitioners; further elaboration is given in the Sect. 4.

The data sources that were used to examine the effectiveness of demarcation as a teaching context were analyzed comparatively for each participant's ideas. Within this process, simple codes were used to represent the participants (e.g. 'P 1' for participant one). The analysis began with a search for patterns in the data in order to derive a viable coding system. In this process, each participant's report was read and conceptual constructs (at the level of words, sentences, or paragraphs) were coded. The list of codes was then narrowed and a new list of codes developed to mechanically sort the data (Gay et al. 2006; Bogden and Biklen 2007). With the help of this sorting process, various themes were identified and synthesized into more abstract constructs which constituted categories (Strauss and Corbin 1998; Maxwell 2005; Creswell 2005) to address research questions. Then, participants' relevant reports were examined again to evaluate the degree of success of the themes and categories for representing the existing data. This also provided the researcher an opportunity to determine the frequencies of the emergence of these themes and categories. When it was concluded that the themes and categories represented the data adequately, the analysis process ended and the distribution of the participants for these themes was clarified. The final conceptual constructs which were developed in terms of the themes and categories are presented in Table 2.

These themes and categories can be interpreted as a brief portrait of the conceptual constructs that emerged frequently in participant reports and classroom discussions. They reflect both the focus of the participants in the context of the study of demarcation and the larger treatment of the NOS. For example, the first category, "nature" includes the themes "mystery" and "materialistic view", which indicated that participants explicitly focusing on nature as an umbrella concept typically referenced the mysteries it is supposed to include or the behaviour of scientists examining it from a materialistic point of view. These arguments were interpreted as highlighting the need for examining the pillars of modern science—ontological and epistemological issues—in science classes before talking about science as a process.

Table 2 Categories and themes of participants' NOS understandings

Category	Theme
Nature	Including mysteries Restrictive materialistic view
Scientists	Honesty Objectivity Second sight Intuition
Scientific inquiry	Correlation Cause and effect Explanation Prediction
Scientific disciplines	Have falsifiable claims Progressive Suggest new problems Propose new solutions

Table 3 Preferences and rationales for demarcation studies in elementary science

Preference	Rationale
Should be used	Pseudoscientific claims in daily life
	Inadequacy of formal science education
	Capturing interest and linking to daily life
Should not be used	Teachers' lack of theoretical accumulation
	Inappropriate cognitive level of students
	Risk of focusing on pseudoscientific claims

The individual participants' reflections about the use of demarcation as a NOS context in elementary science education were also analyzed with a similar methodology. Participants' preferences for using such cases and the rationales that emerged for those preferences are presented in Table 3.

These preferences and rationales were treated as indicative of participants' understanding of and attitudes toward the instruction they received around the issue of demarcation. For example, some of the participants in the first group asserted that whether examined in school or not, students are faced with various pseudoscientific claims in their daily lives and formal science education is inadequate to provide the required skills to demarcate these from scientific claims. Then, they concluded that case studies similar to the one designed for this research should be used in elementary science classes to develop required competencies. So the constructs developed in the Science Technology and Society class provided a foundation for the participants' views of teaching the NOS in similar contexts. Various issues related to teaching the NOS, for instance, the perceived competence of science teachers for such instruction, also emerged from the data.

The themes, categories and rationales given in Tables 2 and 3 should be seen as a brief summary of the analyses which are further examined in the presentation of the results.

4 Results

The results of the research presented in this section are grouped according to the data analysis procedures detailed above. First, participants' understanding of philosophical issues around demarcation criteria are considered, in order to determine the effectiveness of the theoretical preparation phase of the study. The next two sections present findings as they relate to the study's research questions; understandings related to the NOS that were exposed by the participants in the context of demarcation for the case of astrology, and participants' attitudes about the use of similar contexts for teaching the NOS at the elementary school level.

4.1 Participant Understandings of Philosophical Arguments Around Scientific Demarcation Criteria

The criteria listed by participant groups in their reports on philosophical attempts to demarcate science from pseudoscience could be classified into three groups: (1) criteria for knowledge claims, (2) criteria for disciplines and (3) criteria related to practitioners. This list includes the basic premises of philosophical schools of thought that were examined during the first phase of the course; however, additional criteria surfaced after having been

mentioned in various articles, especially those about the behaviour of proponents of pseudoscientific claims.

The criteria mentioned for the evaluation of claims for being scientific were (a) being justifiable by experiments and observations, (b) being falsifiable by experiments and observations, (c) having congruency with scientific (as perceived) content knowledge and (d) being subjected to a consensus in scientific community. The criteria listed for the evaluation of disciplines as a whole for being scientific were (a) having a set of shared rules and values that constitute accepted approaches and methodologies to perform research, (b) suggesting new problems and (c) proposing new solutions. These two sets of criteria mentioned by participant groups were primarily reminiscent of the basic ideas of logical positivism, Popper's falsifiability, Kuhn's position related to paradigms and Lakatos's idea of scientific progress, all of which were examined in class. However, note that this result cannot be used to claim that participants completely understood these criteria and the rationales behind them.

Additional criteria which were related to the practitioners of scientific or pseudoscientific disciplines emerged from the data. The criteria listed for the proponents of pseudoscientific claims included some psychological elements which were not a direct focus of the program: (a) opposing the idea of explicitly presenting the data and methodology used in order to remain esoteric, (b) deliberately presenting misleading data, (c) not aiming for justification but trying instead to persuade people, (d) having a powerful resistance against alternative explanations. The inclusion of this set of additional criteria is perhaps indicative of participants' strong interest in these topics.

Any classification of demarcation criteria (e.g. either for a single claim or for a discipline as a whole) or recognition of the distinctive assumptions behind them, such as those discussed in the Sect. 1 of this article, were not explicitly stated by participant groups in their reports. The general tendency among groups was to develop a list of demarcation criteria and conclude that any or all of these criteria must be satisfied as a condition of being scientific. For example, the participants seemed to accept both confirmation and falsifiability as criteria and were not interested in the conflict between them. Hence, a deep understanding of the philosophical issue of demarcation should not be asserted for the participants at the end of this first phase. In fact, such a meaningful understanding was not expected from the participants, because of the introductory and brief nature of their instruction in philosophy and because of their general lack of theoretical background. But, the aim of having participants become aware of some key demarcation criteria—more than the strict ideas about experimentation that had been widely held by the participants at the beginning of the program—did seem to have been achieved. This basic understanding among the participants was also reflected in their debate of the controversy over astrology's scientific status.

4.2 Understandings Exposed in the Context of Demarcation

Across the second phase of the study, in which the core research questions were examined, participants evaluated astrology as either being scientific or pseudoscientific and justified their positions in two separate reports. The analysis of these reports revealed that the participants aligned themselves before and after the controversy as presented in Table 4.

None of the participants labelled astrology as scientific, but a significant portion of them were uncertain about accepting it as being pseudoscientific. In addition, six of them changed their views of astrology from 'pseudoscientific' to 'uncertain' after the controversy was addressed in class. The main reason given for this shift in perspective was the

Table 4 Participants' views about astrology

	Pseudoscientific	Uncertain	Scientific
Before	24	22	0
After	18	28	0

particular set of studies presented by one group during class, which asserted statistical correlations between astrological signs of people and a range of behaviour variables. It should be noted that because the researcher held a position of power as the classroom lecturer, any indication of a preference in the categorization of astrology could influence the results of the study; for this reason, the researcher adopted the role of an impartial observer and avoided any attempts to directly influence participant behaviour during the discussion.

The first research question addressed by this study was an inquiry into the effectiveness of the context of demarcation for exposing and discussing participants' understandings of the NOS. To this end, beyond the distribution and shift shown above, the rationales and the conceptual constructs proposed by the participants in their evaluations of astrology were the focus of further analysis. The themes and categories which emerged (see Table 2) showed that in general, participants were focused on some relevant aspects of the NOS when making their demarcation-related arguments.

For some of the participants, the critical points of the controversy were the perceived structure of nature and the methods scientists use for trying to understand it. In the case of astrology, 11 participants (24%) criticized scientists for '*having a materialistic attitude*' and described nature as a structure including '*mysteries*' in addition to simply physical phenomena. The belief in the effect of heavenly bodies on human beings seemed to form a foundation for this position and participants tried to support it with various scientific concepts such as magnetic radiation or gravitation:

I believe in the effect of heavenly bodies on us in the form of gravitation or maybe magnetic radiation. Nature has many mysteries and that can be one of these. Approaching everything only at the dimension of matter is an erroneous attitude (P 11).

Criticisms of this argument which occurred during class did not challenge the basic position (e.g. the lack of explanation for such a mechanism or the absence of well-designed investigations concluding such an effect), but rather countered by asserting an alternative conception of nature. According to these participants, an undetectable (perhaps unknown) effect of a heavenly body is possible and scientists, by looking nature only from a materialistic perspective, are mistaken in rejecting such an idea:

Scientists decide stars do not affect the life of humans and astrology is a big lie. How can they easily come to that point? Can scientists or science assert this for only being not measurable or observable? Is nature only made of matter? May be scientists look nature in wrong way or nature operates differently than scientists think (P 21).

Despite the shared belief in heavenly bodies' effect on humans and alternate conceptions of nature, participants who subscribed to these positions were divided on the status of astrology; five of them evaluated astrology as pseudoscientific whereas six of them were uncertain. The second subgroup seemed to be confused about the status of astrology and tended to accept the idea that astrology could eventually become a scientific discipline by

some modifications to its practice. These participants claimed that criticisms about the lack of well-designed investigations and explanations would be overcome in the future:

We know that acupuncture is claimed to be scientific recently in some circles while not before. Of course astrology has some problems but these are not related with its assumptions (effect of heavenly bodies) and, it would be scientific in future. The effect of heavenly bodies could be determined accurately. More disciplined investigations should be done and cranks must be eliminated (P 13).

Although members of the first subgroup mentioned above were certain about astrology's pseudo-scientific status, their belief in its basic assumption about the effects of heavenly bodies on human beings seemed to compel them to address explicitly a critical point about the basic axioms of modern science. They advanced arguments against both the ontologically and methodologically naturalist approaches of science by describing nature as including '*mysteries*' that should be examined in '*alternative ways*'. For these participants, acknowledging that certain topics fall outside of the scope of modern science seemed pejorative; it suggested an inherent lack of value for these topics:

We know that nature includes many mysteries and it could not be restricted to material form. Some of them are not in the scope of investigations yet, but just not being researchable does not mean being nonexistent or invaluable. The scientists should seek alternative approaches for mysteries. The conception of nature and the way of researching nature should be rethought (P 28).

These participants characterized astrology as pseudoscientific, but they did not tend to place astrological beliefs totally outside of modern science (at least, they highlighted the possibility of alternative approaches). Instead of reviewing their beliefs or labelling them as beliefs that could not be satisfied by scientific research, they tried to question the basic assumptions of modern science. They argued that current conceptions of nature and the methodologies utilized to investigate it should be reconsidered. In other words, participants' perceptions of astrology appeared to motivate them to question some metaphysical views about nature; the way scientists examine nature; the quality of scientific research and the general scope of science.

Another argument given by some of the participants ($n = 16$, or 35%) in their evaluation of astrology was related to the behaviour of practitioners of this discipline. These participants claimed that astrology could be scientific, but its practitioners fail to meet some important criteria such as honesty and objectivity. The main reason for astrology not to be considered scientific was presented as a methodological issue, and the possibility for astrology becoming a scientific discipline was highlighted:

Astrology should be scientific and I think some research should be done. But many practitioners mislead the issue and only try to earn more money by tricking people. Second sight, intuition and similar concepts used by them are problematic (P 40).

Within this group a significant portion of participants (10 of 16) labelled astrology as pseudoscientific after the controversy, but these individuals continued to believe in the effect of heavenly bodies on human behaviour. While defending such a belief (which also was presented as a mystery of nature), they criticized second sight and intuition, and emphasized '*objectivity*' as a necessary behaviour for practitioners of a true science. Notably then, these participants cited the activities of a discipline's practitioners as a criterion for demarcation and criticised astrologers for '*tricking people*' or '*being*

dishonest'. In this process, participants revealed an idealized image of scientists, for example as being uniquely objective:

Its practitioners are central for the problem I think. Indeed the field of astrology can become scientific and the effect of heavenly bodies would be determined accurately in the future. But astrologers must be honest as scientists. They only talk about second sight, intuition and etc. but not objectivity (P 29).

In other words, these participants focused on the objectivity of scientists, while disregarding the idea of an objective reality which is examined by scientists. The fact that some of the participants believed in a mysterious effect of heavenly bodies and criticized scientists for their methodologically naturalistic perspective on the one hand, but rejected intuition and second sight and highlighted objectivity as a character of scientists on the other, was contradictory. However, these arguments about the objectivity of scientists and failure of astrologers were in accordance with the practitioner-related demarcation criteria cited by many participants after the first phase of the study.

In the controversy, one group presented the results of various studies which focused on correlations between the astrological signs of individuals and their careers. This topic became widely cited by participants in their controversy reports. Nearly half of the participants ($n = 21$, or 46%) found these studies to be credible, even though some in this group (7 of 21) had labelled astrology as pseudoscientific:

The findings of the research presented that 'Leo' doctors had specialized more than all others in the sample; I think it is a scientific study and explains the effect of heavenly bodies at the time of birth on us (P 32).

These participants claimed that the results of such studies indicated an actual effect of heavenly bodies on human beings and the correlations established were satisfactory to them, even though no detailed description of how the studies been conducted was provided. As with the groups mentioned before, according to these participants, the problem with astrology was not related to the belief in heavenly influence but with some other issue, such as the dishonesty of its practitioners.

It should be noted that the rest of the participants did possess a critical attitude toward these studies and emphasized the terms '*explanation*' and '*cause*' in their reports in order to defend their positions. In addition to the lack of a cause and effect-type of relationship between variables, other problems of bias in research related to the assignment of samples and interpretation of statistical data were referenced in reports:

It is only correlation data and the determination of the sample, explanation of such an effect and etc. are not told. In any research with other professions, samples by independent researchers are not conducted. Science must talk about causes and mechanisms, if not it will not be an explanation, I think (P 17).

These participants, who criticized the studies, focused on the concept of '*explanation*' rather than '*correlation*' and perceived the aim of science to be explaining phenomena with the help of causal mechanisms. These causal mechanisms were emphasized as providing opportunities for scientists to make future predictions, and astrology was labelled as very weak in this regard, since it did not possess any obvious theoretical framework. Although it was not mentioned explicitly as a way to secure methodological objectivity, the confirmation of research results by independent researchers, or the reproducibility of science, was also cited by these participants in discussions as problematic for astrology. In other words, a fair number of participants were able to use NOS concepts such as cause,

correlation, explanation and prediction; and to discuss the aims of science and scientific research with a more appropriate emphasis on the objective and reproducible nature of the subject matter of science instead of relying on the idea of objective scientists.

The evaluation of astrology in general for its individual knowledge claims, as well as in regard to its entire disciplinary standing as a science was not widely addressed in discussions, although some relevant criteria were mentioned in participants' reports. Only a limited number of participants explicitly mentioned the philosophical schools of thought around demarcation issues that were covered in the theoretical preparation phase of the study. Although the discussions about nature, scientific methodologies and the behaviour of scientists around the case of astrology outlined above include signs of some understanding of philosophical demarcation (either in informed or naïve forms), the analysis overall indicates that those philosophical claims were rarely used directly in arguments. Only a small portion of the participants ($n = 13$, or 28%) stated various premises of the philosophical schools of thought in their reports and discussed these actively in the class. The most commonly highlighted topics were the idea of '*falsifiability*' for individual knowledge claims and the extent to which a discipline could be seen as '*progressive*' by suggesting new problems for study and proposing new solutions to those. For instance:

I think we do not have any chance for falsifying an astrologer saying 'you will have good news in near future'. Popper is the one who stated clearly the idea for being scientific I think (P 41).

Most data in this category adopted Popper's falsifiability criterion, and referenced his comparison of relativity to psychoanalysis. Participants mentioned that the predictions made by astrologers in the form of vague, ambiguous claims destroy the chance of being falsifiable.

In addition to this critique, some of the participants also used criteria that were reminiscent of the ones given by Lakatos as theory progressiveness and by Kuhn as problem solving capacity:

Astrology is same and astrologers tell the same tales for thousands of years. How can it be a science with such a static body? Is there any sign of progression? Can we falsify a claim of an astrologer?... Are there any puzzles proposed by astrologers to be solved (P 19)?

These arguments mentioned that for millennia, astrology did not propose new research areas, new theories with greater explanatory power or hence produce new facts. A discipline without '*any sign of progress*' or '*new puzzles to solve*' was labelled as pseudoscientific by some participants, in accordance with Kuhn and Lakatos; these participants concluded that astrology was pseudoscientific, as well. But it should be noted that within this particular line of argument, the general tendency among participants was towards Popper's criterion. '*Falsification*' was seen to be a structural formula that could be applied easily to individual knowledge claims without any need to examine the accumulated knowledge of a discipline in general. Anyway, the portion of this group to whole class was not deemed significant (28% only), although their leading roles in class discussions were noteworthy.

Viewed in their entirety, these results are consistent with the criteria listed by the participants at the end of the first phase of research summarized in previous section. Although the participants did not rely on all the criteria they listed and only a small portion of them considered any traditional philosophical demarcation issues, it is true that the criteria of falsifiability for individual knowledge claims and progressiveness with problem

solving capacity for disciplines were stated and applied appropriately. Participants were found to be interested more often in arguments about the practitioners of disciplines (such as astrologers) and methodologies used within these disciplines. Altogether, the concrete case of astrology appeared to establish an effective context for allowing participants to deeply examine some aspects of the scientific enterprise; their apparent beliefs about the structure and operation of nature provided a foundation for a rich, question-provoking classroom environment. Because the demarcation discussion exposed participants' epistemological and ontological—including metaphysical beliefs about nature and naive as well as informed understandings about many aspects of NOS—there is potential for such an instructional context to help replace or refine individuals' NOS-related conceptual frameworks.

4.3 Views About the Use of the Context of Demarcation

At the end of the second phase of the study, participants wrote individually about the potential use of similar cases in elementary science classes. Participants' reflections were used to interpret their views about their experiences, including their perceived pedagogical competence and rationales for NOS instruction in science education. The analysis of data found the participants were split about the efficacy of teaching the NOS through the context of demarcation in science education. The first group of participants ($n = 28$, or 61%) felt that demarcation arguments based practical examples such as astrology should take place in science classrooms whereas the second group of participants ($n = 18$, or 39%) rejected that point of view. While the two groups did agree on the lack of teachers' understanding of and competence for teaching the NOS, they differed in their perceptions of the implications of that reality.

The majority of the participants (24 of 28) in the first group mainly focused on the fact that students at the elementary school level regularly deal with various pseudoscientific claims (such as those of astrology) in their daily lives because of incessant marketing of such claims in widely-available media sources. These participants argued that preparing future citizens to recognize and refute pseudoscientific claims should be an important goal of science education, one which is in accordance with helping students achieve scientific literacy (a purpose of science education presented to them at the beginning of the course). They seemed to expect students to better understand science in a comparative context, while arguing demarcation of pseudoscientific from scientific:

Our students will read many pseudoscientific arguments everyday in newspapers, watch them on television and see them on the internet. So we must prepare them against such arguments in our science classes and make them understand what science is in a correct way. Looking at science with comparisons from outside of science will make students really understand science. It is like understanding what is hot by experiencing cold (P 26).

Within this first group, some participants explicitly drew attention to the barrage of multi-media messages available in today's society, and individuals' helplessness to deal with them ($n = 11$, or 39%) while arguing that formal science education was inadequate for providing the competence required to critically evaluate pseudoscientific claims among the vast quantities of information. Relating scientific knowledge to daily life by questioning pseudoscientific claims and thus capturing the attention or interest of students was also thought to be a potential motive for teaching in this way:

We must question whether formal science education is adequate against pseudoscientific trends. I think we must focus on such a demarcation issue in our classes directly and take our guard. While teaching the solar system we should also talk about astrology and its claims. The difference between astronomical and astrological claims should be compared and students' attention should be easily captured. They should be directed to question their beliefs that form a base for pseudoscientific claims (P 33).

The approach of comparison teaching, presented by the analogy '*understanding hot by experiencing cold*' and the example of '*talking about astrology while teaching solar system*', was perceived as an effective way of teaching the NOS to students. On the other hand, a majority of the participants in this first group ($n = 18$, or 64% of the group) emphasized the need for educational resources to be supplied within science education programs (at various stages and according to the subjects taught), in order to overcome possible difficulties teachers could face due to their own lack of knowledge of the shortcomings of specific pseudoscientific claims. The participants proposed instructional activities to be performed in parallel to the regular curriculum with the help of these auxiliary resources:

The competency of teachers should be a problem. Some documents and sample activities must be given because such an issue of demarcation should be complicated for them. With the guidance of that auxiliary documents in the unit of 'earth and sky' astrology, in the unit of 'cell division' cancer and alternative medicine should be argued and the process of scientific research, the products of science should be viewed (P 38).

Participants in this study evaluated their own knowledge of complex philosophical issues around scientific demarcation and labelled their competence for teaching as inadequate. Some of the participants in this group reflected on their experiences in the theoretical phase of the study and explicitly stated that, faced with such philosophical arguments for the first time, they had difficulties in interpreting them. This assertion appears to be in alignment with the general profile of the participants (e.g. 61% of them were uncertain in the status of astrology after the class discussion) and also with much of the research on teachers' understanding of the NOS.

This same doubt about teacher competency was the main argument used also by most of the participants who rejected the use of sample cases based on the issue of demarcation in elementary science classrooms (12 of 18 students made this argument). These participants reported the difficulties they experienced during the theoretical preparation phase of the Science, Technology and Society course and additionally pointed out that until this course they were unaware of and uninterested in such philosophical arguments:

As a teacher candidate I did not read any philosophical papers before this course and I could not say that I understand the arguments sufficiently. We can lose the control in class and pseudoscientific claims can become dominant in class, or the teacher himself/herself can be in favour of a pseudoscientific claim unconsciously. I think such an argumentation in class requires a skilled teacher educated for the issue of demarcation which is not the case for most education programs (P 29).

By explicitly mentioning the risk of '*losing control*' and being '*in favour of pseudoscientific claims unconsciously*', participants drew attention to their perceived incompetence and their failure to understand complex philosophical arguments because of their poor

background in such issues. They generalized their self failures to all teachers by affirming the lack of teacher education programs requiring the relevant subjects. These claims differed from those of the members of the first group in that providing some auxiliary resources for teachers was not seen as a solution and that the second group completely rejected the use of demarcation issue in school science classes.

The majority of the participants ($n = 15$, 83%) in this second group also stated the inappropriateness of the cognitive developmental level of students as a reason to reject the use of argumentation about pseudoscientific claims in science classes. Students at the level of elementary science education were generally described as having difficulty with internalizing scientific knowledge in general, and it was thought that arguments about pseudoscientific claims would make this process even more complicated:

Students at elementary level generally experience difficulty in understanding science and its concepts. If we put some pseudoscientific claims near them they will be confused. Such an argument will not make them understand scientific ones more since they do not specialize in science. Everything will become more unclear and complex for them (P 36).

These participants asserted that students at the elementary level can easily accept pseudoscientific claims since they do not have adequate scientific background. The idea of using pseudoscientific claims comparatively with scientific ones was seen as a dangerous strategy which would not increase students' understanding of science. Unlike the ideas expressed by some participants in the first group, these individuals did not emphasize the fact that whether examined in formal science coursework or not, students are faced with pseudoscientific claims in their daily lives. They believed instead that understandings about science and scientific knowledge should not be developed comparatively and such comparisons would be too complex and confusing for elementary students.

Furthermore, an important portion of this second group ($n = 10$, or 55% of the group) developed some additional arguments in support of rejecting the use of sample cases based on the issue of demarcation. These participants emphasized the notion that pseudoscientific fields such as astrology would be potentially more interesting for students and more easily grasp students' attention. Participants felt that the possibility of students focusing on pseudoscientific claims over scientific ones, without caring about the criteria of demarcation, was a significant risk of undertaking this instructional strategy. In addition, the participants also highlighted the difficulty in arriving at logical demarcation conclusions for some cases such as instances of a 'sixth sense':

Pseudoscientific claims will be more interesting for students and talking about orbits, gravitation, seasons with their explanations instead of astrological signs will not be preferred by them. On the other hand some arguments such as sixth sense, out of body experiences and etc. evaluated as pseudoscientific by scientists would not be concluded easily (P 8).

The perceived speculative and interesting nature of pseudoscientific claims and examples such as the sixth sense, out-of-body experiences and the like were also taken by the researcher to reflect the participants' own views about these claims. The expression '*evaluated as pseudoscientific by scientists*' was ambiguous about whether the participants thought likewise, so the asserted difficulty in arriving at demarcation conclusions was noteworthy. The data suggest that participants' prior acceptance of metaphysical

phenomena may have contributed to their willingness to be more careful about dismissing astrology as pseudoscientific, or more willing to be critical of the way science is practiced and to seek the inclusion of supernatural phenomena in science's objects of study.

5 Discussion

Overall, the issue of demarcation was determined to be an effective NOS teaching context for the purpose of exposing pre-service teachers' ontological and epistemological conceptions related to science. The structure of nature; the methods scientists use for examining nature; correlation; cause; explanation; objectivity; intuition; characteristics of scientists and the aims of science were NOS-related concepts that emerged in class discussions. The introduction of these topics into class conversations provided an opportunity to address conflicting ideas—for example, between science's search for materialist explanations of natural phenomena and individuals' belief in a mysterious, non-material element of nature. A review of some pillars of modern science, such as the power and limitations of science and presuppositions about the natural world (Gauch 2009) could be used effectively with students for purposes of developing clearer understanding of the nature of science. Focusing on the ontological principles presupposed by various disciplines and presenting modern science as an epistemological endeavour emanating from a core of particular ontological metaphysical principles such as uniformity, substance and causality also could be a meaningful strategy in this approach (Dilworth 2006).

Based on the results of this study, the methods and behavior of disciplinary practitioners should also be examined in contrast to these ontological principles and pillars of science; in particular, the idea of an objective reality being researched by scientists should be addressed. Some of the participants in this study advanced an idealized image of scientists to demarcate them from astrologers and in doing so emphasized a methodological objectivity instead of an ontological one. They rejected intuition and described scientific research as akin to a mechanical system. In addition, the discussions arising out of a presentation of astrological research which confused some participants about astrology's pseudoscientific status provided a good anchor to introduce and more carefully consider NOS concepts such as scientific theory, explanation, causality and correlation and their relationships to the concept of scientific evidence.

Within such a teaching context, participants were faced with trying to answer basic philosophical questions about science in terms of both knowledge and processes of knowing, as suggested by Matthews (1998); pre-service teachers had the chance of engaging in a reflective epistemic dialogue about how scientific knowledge is formed (Bartholomew et al. 2004). So, in the case of this study, the context of demarcation was a meaningful instructional tool used effectively in NOS teaching; it provided the course instructor the chance to determine individuals' pre-existing NOS-related understandings, including their metaphysical beliefs. Using this type of instructional context can give instructors the opportunity to plan targeted activities to develop students' NOS understandings by forcing them to critically evaluate their beliefs and examine possible misconceptions about various aspects of science. This approach should also be viewed as aligned with Lilienfeld et al. (2001) suggestion that students should be faced with problematic and especially pseudoscientific assertions in order to develop critical thinking skills. This instructional strategy also helps remedy critiques of formal science education pointing to its failure to provide individuals the required skills to demarcate pseudoscientific claims from scientific ones (Castelao 2002).

These critiques should be treated seriously because past research has not found any meaningful correlation between the amount of content knowledge individuals have and their ability to critique pseudoscientific claims (Mats 2007), whereas an increase of the belief in paranormal activities with an increase in the level of education has been seen (Bunge 1989). Others have determined that with a focus on the demarcation of science from pseudoscience, a significant reduction in paranormal beliefs can occur (Morier and Kepperts 1994) and an improvement in one's competence in evaluating flaws in reasoning (Wesp and Montgomery 1998) can be achieved. But, it must be noted that the concept of pseudoscience should be used carefully and distinguished from religious and other kinds of metaphysical claims, in order to not alienate students who may be deeply religious (Lienfeld 2004).

Teachers would ideally have considerable time and multiple occasions for studying philosophical controversies over issues such as demarcation, but most teacher education programs, including those in Turkey, do not afford teachers such opportunities. The short intervention performed in this study to introduce the issue was clearly not adequate, but helpful as a starting point; the fact that some participants were able to use criteria of falsifiability for assessing individual knowledge claims and to judge disciplinary progressiveness with problem solving capacity would indicate modest success in this regard. Although participants did not explicitly demonstrate a deep understanding of demarcation criteria or the philosophical evolution and classification of arguments surrounding them, the instructional approach taken in this study could claim some success in making participants aware of scientific demarcation criteria more sophisticated than a student's typical 'confirmation by experience' approach.

As teacher candidates, participants also expressed positive views about the potential for using arguments based on the issue of demarcation in science classrooms, and this should also be as a measure of some success for the approach taken in this study. In general, participants were in favour of using sample demarcation cases in science classes although some participants had justifiable criticisms of this strategy. In particular, participants asserted that science can be understood more accurately as a process if it is examined comparatively with pseudoscience and they emphasized that students' exposure to pseudoscience is a fact of daily life whether or not it is addressed in class, and consequently argued for purposeful treatment of these claims in science classes. On the other hand, doubts about the competence of teachers for guiding such arguments, the cognitive development level of students at elementary level and the risk of losing the focus of demarcation arguments because of the interesting nature of pseudoscientific claims were also expressed by the participants in this study.

The most frequent worry about using demarcation controversy discussions in school science classrooms was the teachers' perceived lack of preparation for such teaching. This is of serious concern, since distinguishing between science and pseudoscience requires a full and complete grasp of the NOS (Matthews 1998); a requirement to teach it in school settings may force some teachers to simultaneously develop their own NOS understandings. Although such in-practice conceptual development was not mentioned explicitly, some of the participants seemed to hint at this approach by suggesting that auxiliary resources be provided to teachers to overcome possible problems they should be faced with in teaching demarcation controversies. This is not necessarily a problem, as previous research has shown that teachers' perceptions about the NOS may be formed as much through their experiences actually teaching science as through their preparation for teaching science (Nott and Wellington 1996). Finally, the fact that a majority of participants in this study were in favour of using similar cases in science classes can not project

the future behaviors of these candidates in regard to NOS teaching with any certainty; an actual follow-up of participants is out of the scope of this study. It is well known that teachers' beliefs about the nature of student learning and power relations (Tobin and McRobbie 1997), the mediating effect of the epistemological status of both teachers and students (Laplante 1997), and differences in the explicitly espoused theories and actions of individuals (Argyris and Schon 1974) are powerful factors which all affect the actual instruction implemented by classroom teachers.

Teacher candidates' generally positive attitudes toward the inclusion of arguments about pseudoscientific claims in science education would seem to be in accordance with the current tendency of focusing on the relationship between culture and science in the science curriculum. This trend emerged in science education in the 1990s as a result of several factors, including the rise of constructivism, critical attitudes towards Western Modern Science (WMS) and the critique of the Western attitude toward other ways of knowing (El-Hani and Mortimer 2007). This tendency has provoked some science educators to question the culture they are teaching when they teach science and to critically consider the criteria they should use to demarcate science from other societal practices. Although the inclusion of such arguments in science education can potentially ignite philosophical arguments about WMS and other ways of knowing related to their epistemological status—a controversy about epistemological universalism and multiculturalism—these arguments need not be avoided. In considering the relationship between science and culture, science educators should seek a middle ground between scientism, which imposes hegemony and asserts the superiority of science over other practices, and radical multiculturalism, which devalues or rejects some of the properties that make science worthwhile to study (El-Hani and Mortimer 2007). Such an instructional multicultural science education approach would be appropriate for taking into account the diversity of students' worldviews, sensitively addressing other ways of knowing, providing discussions for non-scientific ideas in the science classes, enriching students' conceptual ecologies and addressing the historical, philosophical, socio-cultural dimensions of science, which should be the central aspects of formal education.

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